1 Introduction

This document presents the results of the baseline risk assessment (BLRA) for human health and ecological risk in the Lower Fox River and Green Bay, Wisconsin. The BLRA is being undertaken as part of the Fox River Remedial Investigation and Feasibility Study (RI/FS), and is intended to provide an assessment of risks to human health and the environment that will support selection of a remedy to eliminate, reduce, or control those risks. The overall programmatic goal is to develop an RI/FS report that is sufficient to support the selection of an approach for site remediation, and then to use this data in a well-supported Record of Decision (ROD). The ROD defines the cleanup alternative selected for the site.

This RI/FS report is consistent with the findings of the National Academy of Science's National Research Council Report entitled *A Risk Management Strategy for PCB Contaminated Sediments* (NRC, 2001). Based on national and growing concern regarding the long-term management of PCB-contaminated sediments, the National Academy of Sciences (NAS) was mandated by the United States Congress, via the National Research Council (NRC), to address the complexities and risks associated with managing PCB-contaminated sediments. The NRC was tasked with reviewing the availability, effectiveness, cost, and effects of technologies used for the remediation of sediments containing PCBs. The results of their findings were published in a document titled *A Risk Management Strategy for PCB-contaminated Sediments* (NRC, 2001). Based on their review of PCB effects at several sites nationally, the NRC also concluded that PCBs in sediment do pose a chronic risk to human health and the environment, and that these risks must be managed. The NRC recommended that remedies should be site-specific and risk-based, and that no one remedy (dredging, capping, or monitored natural recovery) is applicable or preferred for all sites.

The recommendations of the NRC were adapted by the United States Environmental Protection Agency (EPA) in a document titled *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA, 2002). EPA used the guiding principals defined by the NRC to develop a set of 11 risk management principles for application at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Resource Conservation and Recovery Act (RCRA) sediment sites. The EPA guidance principles specify use of scientific, risk-based, site-specific remedy decisions using an iterative decision process, as appropriate, which evaluates the short-term and long-term risks of all potential cleanup alternatives. These principles are also consistent with the nine remedy selection criteria defined in the National Contingency Plan

(NCP) (40 CFR Part 300.430) and application of these principles does not affect existing statutory and regulatory requirements. A comparison of the NRC-developed and the EPA sediment management principals is given in the white paper titled *Applicability of the NRC Recommendations and EPA's 11 Management Principles* in the Responsiveness Summary.

The Lower Fox River and Green Bay RI/FS followed the guidance set forth by both the EPA and the NRC. These included:

- Using EPA risk assessment frameworks (EPA, 1989 for human health risk; EPA, 1997 and 1998 for ecological risk) that were based on the framework developed by NRC in 1983 which recommended a tiered and iterative approach;

- Using an extensive body of site-specific scientific information and data to bound the problem, and by calibrating and defining the uncertainty of models that were used in the risk assessment and feasibility study;

- Defining the problem in a site-specific manner through review of all existing scientific information in a preliminary assessment;

- Calibrating and defining the uncertainty of models that were used in the assessment; and by

- Structuring the documents so that a range of site-specific risks to human health and the environment were delineated, and articulating Remedial Action Objectives (RAOs) around which to structure potential remedial alternatives.

EPA's 11 risk management principles also are covered by the above bullet, as well as through public involvement; development of sophisticated fate, transport, and bioaccumulation models; early involvement of trustee groups; and implementation of three demonstration projects to test potential remedial technologies. These are discussed throughout the FS.

The RI/FS is being conducted under contract to the Wisconsin Department of Natural Resources (WDNR). While this is a state-lead effort, the overall assessment follows the procedures and paradigms developed as part of CERCLA and National Contingency Plan (NCP) (i.e., "The Superfund Program"). Specific procedures are addressed in relevant sections below.

In addition to the WDNR, this BLRA received review and comment from the EPA, United States Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), and the Menominee and Oneida Nations.

1.1 Statement of the Problem

The area investigated for this BLRA includes the Lower Fox River and all of Green Bay. The Lower Fox River is 39 miles long and extends from the outlet of Lake Winnebago, flowing north, to Green Bay (Figure 1-1). Green Bay begins at the mouth of the Lower Fox River, extends north for approximately 193 kilometers (km) (120 miles), and has an average width of 37 km (23 miles) (Figure 1-2).

The Lower Fox River is the most industrialized river in Wisconsin, and has had reported water quality problems since the early 1900s. Beginning in the mid-1800s, forests were cleared for lumber and the cleared land was converted to agriculture. The runoff from farmlands increased the sediment and nutrient loads to the river and bay. The expanding paper industries and communities discharged increasing amounts of untreated sewage and industrial wastes into the river and, ultimately, the bay. The Lower Fox River received discharges from 15 pulp and/or paper mills, one electrical generating facility, and eight municipal wastewater treatment plants. Green Bay's ability to trap nutrients hastened its degradation under the increasing loads of biological oxygen-demanding wastes and suspended solids (Smith *et al.*, 1988). Until the early 1970s, the extreme southern portion of Green Bay (including the 11 km [7 miles] of the Fox River downstream of the De Pere dam) was a shallow (1- to 5-meter [3- to 16-foot] depth), eutrophic water body which received virtually all of its nutrient loadings from the Fox River and the city of Green Bay.

In the early 1970s, polychlorinated biphenyls (PCBs) were discovered in sediments and water in the Lower Fox River. PCBs were also detected in many fish species and birds in the Lower Fox River and Green Bay. Between 190,000 and 375,000 kg (418,878 and 826,734 pounds) of PCBs have been released into the Lower Fox River over the period from 1957 to 1992 (WDNR, 1998a).

In 1977, the WDNR issued the first warnings regarding human consumption of trout, salmon, and carp principally due to elevated levels of PCBs. Since 1977, WDNR has annually issued fish consumption advisories for most common species in the Lower Fox River and Green Bay. Additionally, a waterfowl consumption advisory exists for mallard ducks taken between Lake Winnebago and the northeast limits of Kaukauna.

Extensive evaluations of PCB contamination in sediment, fish, and wildlife have been conducted on the Lower Fox River and Green Bay by the WDNR, the EPA, and the USFWS. These studies included measurement of concentrations in sediments, surface water, fish, and avian species; fate and transport modeling of PCBs; and evaluations of environmental impacts.

While, historically, the concerns on the Lower Fox River have largely centered on PCBs, other studies have identified additional chemicals that could pose risks to human health and ecological receptors on the Fox River (Sullivan and Delfino, 1982). For example, Sullivan and Delfino (1982) found more than 100 chemicals in Lower Fox River sediments, water, and fish tissues. More recent estimates list up to 362 potentially toxic substances in the river and southern Green Bay (WDNR, 1993), including mercury, total polynuclear aromatic hydrocarbons (PAHs) and ammonia. Other contaminants found in specific locations of the river and Green Bay include arsenic, chromium, copper, lead, zinc, 4,4'-dichlorodiphenyl trichloroethane (DDT), 4,4'-dichlorodiphenyl dichloroethylene (DDE), dieldrin, and pentachlorophenol (PCP). Presently, of the potentially toxic substances found, PCBs are considered to be the primary chemical of potential concern (RETEC, 1998b). Adverse effects associated with these substances can include altered benthic community structure and reproductive impairments in fish-eating birds.

In order to focus the RI/FS process, a Screening Level Risk Assessment (SLRA) was conducted to evaluate which chemicals in the Lower Fox River system posed the greatest degree of risk to human and ecological receptors. The SLRA for the Lower Fox River and Green Bay evaluated the potential for human health and ecological risks associated with contaminants in sediments, surface waters, and biota. Based upon those results (see Section 2, below), eight chemicals of potential concern (COPCs) were identified by WDNR (letter from Bruce Baker, August 3, 1998; Appendix A) for carrying forward into the BLRA. These are:

- PCBs (expressed as total, PCBs and PCB coplanar congeners);
- 2,3,7,8-Tetrachloro-*p*-dibenzodioxin (TCDD);[1]
- 2,3,7,8-Tetrachloro-*p*-dibenzofuran (TCDF);[1]

[1] Although 2,3,7,8-TCDD is the most toxic dioxin congener, all structurally related dioxin and furan congeners will be evaluated for toxicity based on the toxicity equivalency method. The dioxin and furan congeners that will be evaluated are those that have been measured in site media and those that have toxic equivalency factors (TEFs).

- 4,4'-Dichlorodiphenyl trichloroethylene (DDT) and its metabolites (DDE, DDD);
- Dieldrin;
- Arsenic;
- Lead; and
- Mercury.

1.2 Objectives of the Baseline Risk Assessment

The BLRA for the Lower Fox River and Green Bay focuses on defining the current (or baseline) human health and ecological risks associated with the COPCs identified in the SLRA. The specific media of interest are the sediments, surface waters, and biota in the Lower Fox River from Lake Winnebago into the Green Bay estuary. The BLRA will quantify the levels of risk and identify potentially significant risks by distinguishing chemicals that pose the greatest potential for risk from those that pose negligible risks.

The primary objectives of the BLRA are to:

- Define the sources, receptors, and pathways at risk
  - Define the sources of contaminants in the river
  - Identify the critical fate and transport processes
  - Define the human health and critical receptors potentially at risk
  - Describe exposure pathways
  - Select assessment endpoints
  - Develop a defensible conceptual model
- Identify the extent of exposure
  - Critically evaluate all data and determine which points in sediment, water, and tissues may be defensibly used for the BLRA
  - Using site-specific data, determine area-wide average concentrations of COPCs
  - Develop site-specific exposure scenarios to be used in the risk estimations

- Determine the extent and likelihood of actual or potential impacts

  - Select how risks to human health and the environment will be measured
  - Evaluate toxicity values from literature and database sources
  - Derive and defend levels of COPCs in environmental media that place receptors at risk
  - Quantify the current level (baseline risk) to human health and the environment

- Describe the uncertainty associated with the characterized risk

  - Identify those assumptions and data gaps which may contribute to the over/underestimation of risk

- Evaluate risk-based sediment quality thresholds (SQTs) for PCBs

  - Determine PCB sediment concentrations that would not result in accumulations to fish tissues at levels that exceed acceptable human health cancer risk levels ($>10^{-4}$, $>10^{-5}$, $>10^{-6}$) or noncancer risk hazard indices (HQ > 1)
  - Identify PCB sediment concentrations that would not result in unacceptable risks to ecological receptors (e.g., no observed effect level [NOEL], lowest observed effect level [LOEL], 20 percent effect concentration [EC_{20}], and 30 percent effect concentration [EC_{30}])

1.3 Geographic Boundaries of the Baseline Risk Assessment

The Lower Fox River and Green Bay, Lake Michigan are located in northeastern Wisconsin within the eastern ridges and lowlands of the state. The Lower Fox River is defined as the 63-km (39-mile) segment of the river beginning at the mouth of Lake Winnebago and terminating at the mouth of Green Bay (Figure 1-1). Flowing north, the Fox River is the primary tributary that leads into lower (southern) Green Bay. The BLRA also includes Green Bay.

For the BLRA, the reaches of the Fox River discussed in this report are as follows:

- **Little Lake Butte des Morts Reach:** the river reach from the outlet of Lake Winnebago to the city of Appleton, including Little Lake Butte des Morts (LLBdM);

- **Appleton to Little Rapids Reach:** the river reach from approximately Appleton to Wrightstown;

- **Little Rapids to De Pere Reach:** the section of the river from Little Rapids to the De Pere dam;

- **De Pere to Green Bay Reach (Green Bay Zone 1):** the approximately 11 km (7 miles) of river downstream from De Pere to the mouth of Green Bay; and

- **Green Bay:** the entirety of Green Bay that begins at the mouth of the Lower Fox River and extends north for 193 km (120 miles) (Figure 1-2). Green Bay is narrow compared to its length; on average, Green Bay is 37 km (23 miles) wide. Within the comprehensive Green Bay Mass Balance Study (WDNR, 1995), the bay was further evaluated in four zones.

  - **Zone 1:** corresponds to the De Pere to Green Bay reach in this study (approximately 11 km or 7 miles),
  - **Zone 2:** defined as the lower bay area to a line transversing the bay at Little Tail Point (approximately 13 km or 8 miles),
  - **Zone 3:** runs north until just south of Chambers Island (approximately 76 km or 47 miles), and
  - **Zone 4:** includes all of the northern bay, including the islands marking the entrance to Lake Michigan (approximately 93 km or 58 miles).

All zones can be considered as "east" and "west" reaches based upon a line drawn from Chambers Island to the mouth of the Fox River, where zones on the west side of the bay are denoted as "A" and those on the east side of the bay are denoted as "B." For the purposes of evaluating risk in zones 1 through 4, only Zone 3 will be independently evaluated as Zone 3A (the west side) and Zone 3B (the east side). This distinction is noted for Zone 3 because much of the area in Zone 3B is part of the Lower Fox River depositional zone (Manchester-Neesvig *et al.*, 1996) and, therefore, potentially quite different in terms of risk than Zone 3A. Further detail regarding descriptions of the river reaches and Green Bay zones is provided in the Remedial Investigation.

1.4 Organization of the Baseline Risk Assessment

The remainder of this BLRA is organized as follows:

- **Section 2, Review of the Remedial Investigation,** presents a summary of the *Remedial Investigation for the Lower Fox River* (RETEC, 2002a) that includes the overall environmental setting, site description, previous studies, contaminants known to exist at the site, and fate and transport processes, as it relates to the BLRA.

- **Section 3, Summary of the Screening Level Risk Assessment,** discusses the relevant pathways, receptors, and chemicals of potential concern identified in the SLRA.

- **Section 4, Sediment, Water, and Tissue Chemistry Data,** presents the sources of analytical data, the compilation into a single database, and an evaluation of the data quality for use in the BLRA.

- **Section 5, Human Health Risk Assessment,** includes the conceptual site model identifying potential sources of contaminants, migration and exposure pathways for human receptors, and the relevant exposure assumptions and risk calculations.

- **Section 6, Ecological Risk Assessment,** includes the problem formulation, description of the affected ecosystem, a conceptual site model for the receptors on the Lower Fox River, selection of assessment and measurement endpoints, characterization of exposure and of risk, and a description of the uncertainties in the ecological BLRA.

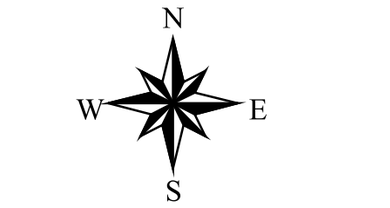
- **Section 7, Sediment Quality Thresholds,** uses the risk levels identified to human health and the environment to develop concentrations in sediments that should not result in exceedances of these risk thresholds.

- **Section 8, References,** includes the literature, studies, internet websites, and personal communications used to build the BLRA.

1.5 Section 1 Figures

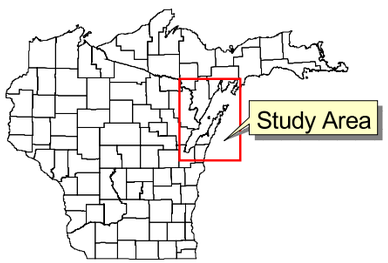
Figures for Section 1 follow this page and include:

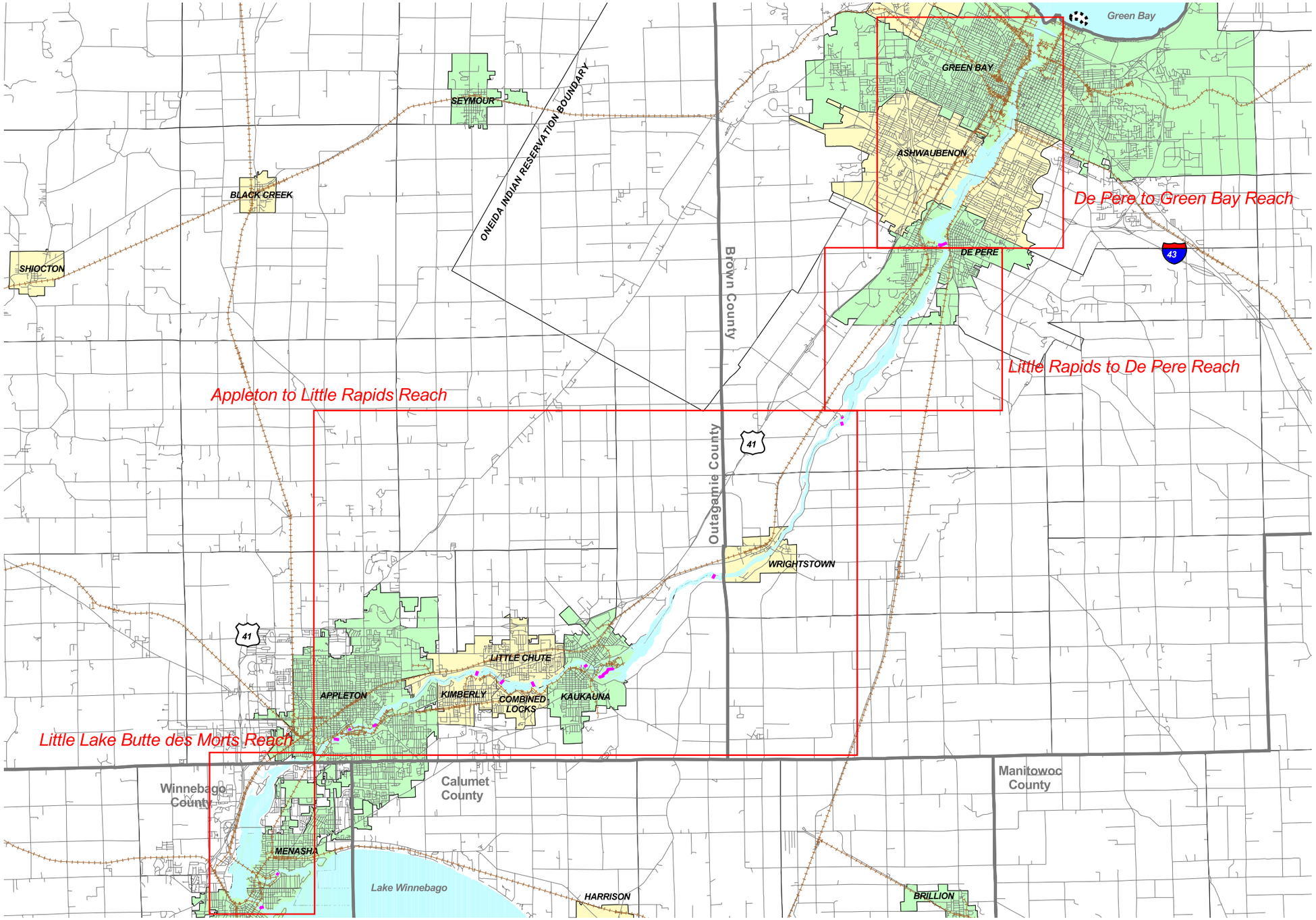
Figure 1-1 Lower Fox River Study Area
Figure 1-2 Green Bay Study Area



County Boundaries
Dam Locations
Railroads
Roads
Water

Civil Divisions
City
Township
Village



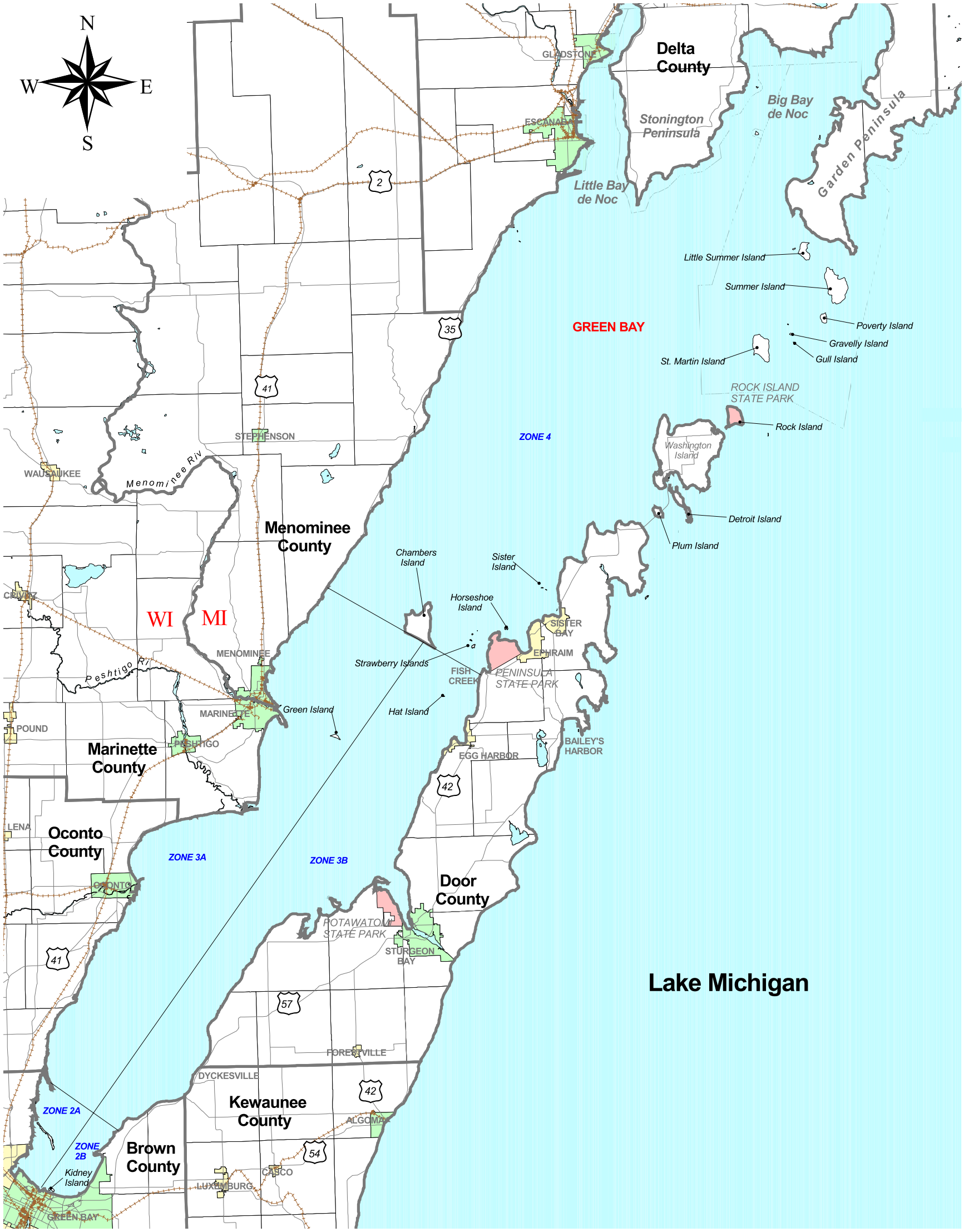


3 0 3 6 Kilometers

3 0 3 6 Miles

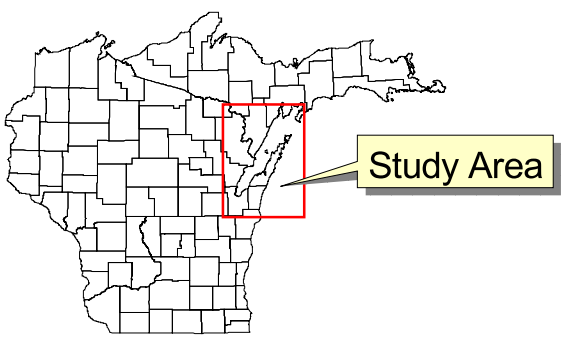
NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Study Area FIGURE 1-1	REF NO: RA-14414-425-1-1 CREATED BY: SCJ PRINT DATE: 3/14/01 APPROVED: AGF



County Boundaries
Railroads
Roads
Wisconsin State Parks
Water

Civil Divisions
City
Township
Village



5 0 5 10 15 Kilometers

5 0 5 10 Miles

NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Study Area	REF NO: RA-14414-425-1-2
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 1-2	APPROVED: AGF